4.2

SPATIAL DISTRIBUTION OF FIRE SEASON AND ENSO EFFECTS ON THE ISLAND OF SUMATRA, INDONESIA

Robert Field[1], Caren Dymond, William de Groot and Bryan Lee
Canadian Forest Service, Edmonton, AB, Canada

1. INTRODUCTION

1.1 Project Background

For the past several decades fires and associated haze have increasingly affected the economies, health and environment in Southeast Asia. During the most recent fire and haze disaster of 1997-98, damage estimates exceeding four billion US dollars have been reported, excluding many direct and indirect costs. A thorough examination of the causes and impacts of these events is given by Badawi et. al. (1998).

In an attempt to prevent losses of such magnitude from occurring again, the Environment Ministers in the region, through the Haze Technical Task Force, proposed development of a regional Fire Danger Rating System (FDRS) to provide a better understanding and early warning of dangerous fire conditions. The Southeast Asia FDRS Project is a multi-partner initiative being led by the Canadian Forest Service to achieve that goal.

1.2 Fire Climate Analysis

In addition to anthropogenic factors, climate has been attributed as a major factor in these fire and haze events (Schweithelm 1999). The wet-dry seasonality of the tropics has the potential for long droughts to create dangerous fire conditions. While agricultural studies of climate variability exist, there is little information on how that spatial variability creates differences in the length and timing of fire seasons. This information can be used in fire management for distributing limited fire monitoring and fire suppression resources.

The wet-dry seasonality may be exacerbated by reduced rainfall caused by the El Nino – Southern Oscillation (ENSO) (Harger 1995). El Nino years have repeatedly been associated with severe burning conditions in parts of SE Asia (Kita et. al. 2000, Siegert and Hoffmann 2000). While ENSO impacts are generally understood, there has been no examination of the spatial variability of these effects. Furthermore, ENSO impacts in the region must be characterized specifically in terms of fire danger. This information can improve the use of seasonal ENSO forecasts in fire management planning at the executive level.

The goals of this historical analysis are to determine the inter-annual and spatial variation of fire season onset, severity and duration, and the spatial impacts of the ENSO phenomenon. Presented here are preliminary results for the Indonesian island of Sumatra, which is the pilot study area for the SE Asia FDRS Project.

2. METHODS

2.1 The Canadian FWI System

The Canadian Forest Fire Weather Index (FWI) system (Van Wagner 1987) provides relative numerical ratings of fire potential using daily weather inputs of 12:00 LST temperature, relative humidity, wind speed and 24-hour

[1] Corresponding author address:
Robert Field, Canadian Forest Service
Northern Forestry Centre, 5320 122 Street,
Edmonton, AB, Canada T6H-2S5
email: rfield@nrcan.gc.ca

rainfall. The FWI System is composed of three moisture codes, which track fuel moisture content in different layers of the forest floor, and three behaviour indices which provide relative indicators of fire behaviour.

This study used the Drought Code (DC) component of the FWI System to represent fire danger in peatlands. The DC estimates moisture content of deep (10-20 cm), compact organic layers and is used as an indicator of long-term drying and deep, smouldering fires (Turner 1972, Van Wagner 1987, McAlpine 1990). Increasing DC values indicate drier conditions in the lower organic fuel layers. The DC has an unbounded scale, but ranges in Canada from 0 in the spring to a typical maximum value of 800 in very dry areas of western Canada in the fall (McAlpine 1990). Ignition of deep organic sphagnum layers occurs at a moisture content near 130% (Frandsen 1997) which is estimated to occur in that material at DC=350 (Lawson and Dalrymple 1996). Complete combustion of this layer to 25cm deep is estimated to occur near DC=700 (Lawson et al. 1997). Fires in Sumatran peatlands are a major contributing factor to smoke production (Ikegami et. al. 2001), and as such, the DC was used in this study to indicate seasonal fire danger in Sumatran regions of deep organic soils.

2.2 Drought Code Calculations

The DC uses daily temperature, rainfall and the previous day's DC to obtain the DC for the current day. Daily weather summaries for 11 Sumatran weather stations were obtained from NOAA's National Climatic Data Centre for the period of 1994 to 2001. Periods of missing data in the NCDC data set were augmented using archived data at the Northern Forestry Centre, currently being used for operational systems. Station locations and record completeness are shown in Figure 1.

Since the DC is a cumulative index, it requires that the input weather data be continuous. In the case of missing data at a station, input values were estimated from nearby weather stations, using the inverse-distance weighting scheme implemented in the Spatial Fire Management System (SFMS) (Englefield 2000).

The resulting DC values at the 11 stations with completeness above 85%, were analyzed to derive monthly quartiles to represent seasonal change in fire danger. Quartiles were used to represent the non-normal distribution in the graphical analyses. Monthly DC normals were defined as the median value of all days of a month, over all years. DC values from the 1997 strong ENSO event were graphically compared to the DC normals.

WMO	NAME	LAT	LON	% COMPLETE
960010	SABANG	5.9	95.3	86
960090	LHOKSEUMAWE	5.1	97.2	88
960350	MEDAN	3.6	98.7	99
960730	SIBOLGA	1.6	98.9	96
961090	PAKANBARU	0.5	101.5	94
961630	PADANG	-0.9	100.4	92
961710	RENGAT	-0.5	102.3	96
961950	JAMBI	-1.6	103.7	32
962210	PALEMBANG	-2.9	104.7	90
962490	TANJUNG PANDAN	-2.8	107.8	89
962530	BENGKULA	-3.9	102.3	88
962950	TELUKBETUNG	-5.3	105.2	89

Figure 1. Sumatra WMO weather station map and percent completeness of records.

Maps of fire danger were built for October, the peak of the 1997 fire season. The input data for the normals map was limited by data to 1994 to 1998. The median value in each map pixel was calculated on a cell-by-cell basis using daily DC surfaces constructed using the data from all weather stations. The normals map illustrates the spatial variability in fire danger across Sumatra. Comparing the normals map with the October 1997 median map illustrates the spatial variability in ENSO effects on fire danger.

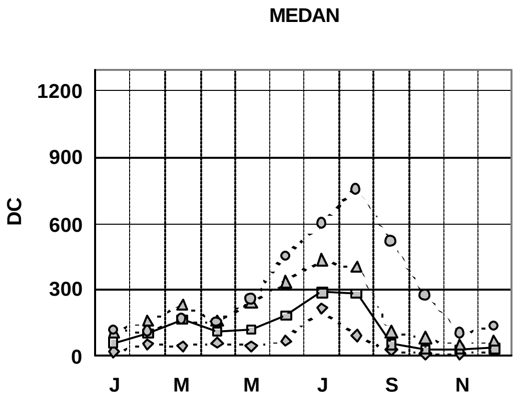

Figure 2. Monthly Drought Code quartiles for Medan station.

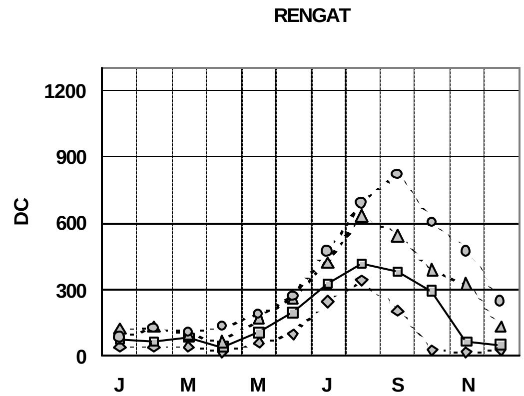

Figure 3. Monthly Drought Code quartiles for Rengat station.

25%
50%
75%
50%, 1997

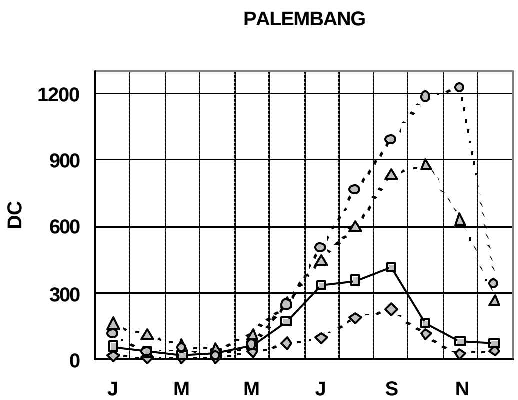

Figure 4. Monthly Drought Code quartiles for Palembang station.

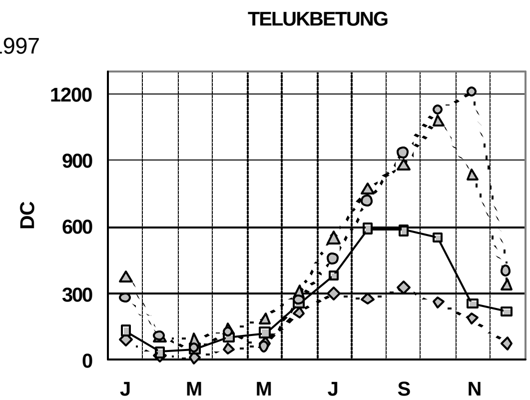

Figure 5. Monthly Drought Code quartiles for Telukbetung station.

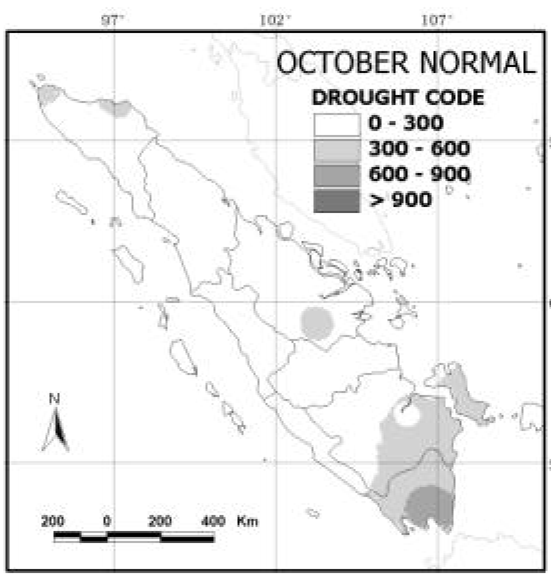

Figure 6. Map of October normal (median) Drought Code. Black outlines provincial boundaries.

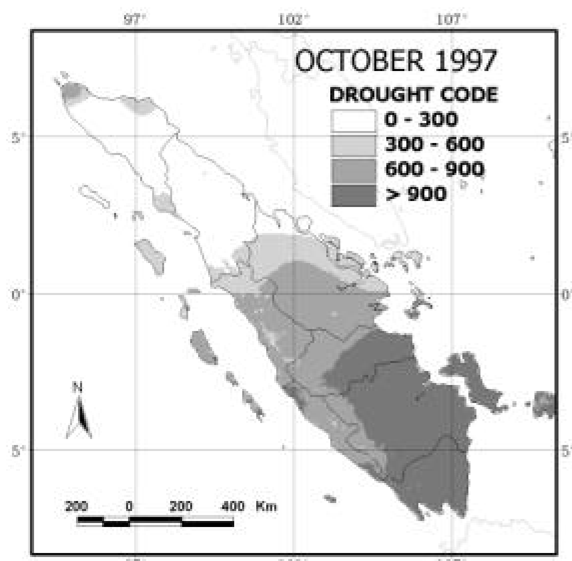

Figure 7. Map of October 1997 median Drought Code. Black outlines provincial boundaries.

3. RESULTS AND DISCUSSION

The impact of spatial climate variation on fire danger is well-illustrated by comparing monthly DC normals between Medan weather station in the north (Figure 2), to Palembang station in the south (Figure 4). In Medan, the DC typically reaches a seasonal maximum of 286 during July and August, with a more moderate local maximum of 160 during March. The timing of these two maxima correspond well to 30-year rainfall patterns recorded in Medan, which indicate two periods during the year of lower rainfall, associated with Asia-Australia Monsoon system (Jun-Ichi and Sribimawati 1998). Both of these values are below a probable DC ignition threshold of 350. In Palembang, the DC typically crosses the ignition threshold in August, reaches a seasonal maximum of 411 during September, and decreases below the ignition threshold during the following month. The southern part of the the island has a longer and more severe fire season.

During the 1997 ENSO event, the Medan DC increased through August, achieving a maximum value of 927, and crossing below the ignition threshold in October. In Palembang however, extreme drought conditions prevailed longer than normal until November, when the DC reached a maximum of 1223. In both the south and the north, ENSO resulted in a longer and more severe fire season than normal. In the north, Medan, the peak fire season was delayed by one month past normal, but in the south, the peak was delayed by twice that. Intermediate stations show the gradation of the climate from south to north Sumatra (Figures 2-5).

The map of October normals (medians) illustrates the spatial variability in the end of the fire season (Figure 6). The weather of northern two-thirds of Sumatra has moved into the rainy season, effectively ending the fire danger. However, the rains have just started in the southern portion of Sumatra, so there is still some potential for land and forest fires.

The map of October 1997 medians illustrates the spatial variability in the severity of fire danger, with higher fire danger in the south (Figure 7). Furthermore, in comparing the 1997 median values to the normals map, the fire season has been extended into October for the central provinces of Sumatra.

4. FUTURE STUDIES

This historical analysis will be conducted with an increased station density and over a longer time frame and larger area for the SE Asia FDRS Project. Results from this fire climate study will provide an analysis of Indonesian fire regimes and provide the framework to build fire management systems and decision aids specific to this region. These tools will assist in the development of fire management policy and procedures to prepare in advance of serious fire situations and mitigate potential impacts.

4. ACKNOWLEDGEMENTS

The authors wish to thank Ir. Guswanto (Indonesia Meteorology and Geophysical Agency), Orbita Roswintiarti (Indonesia National Institute of Aeronautics and Space) and Michael Brady (Canadian Forest Service) for their contributions to this study. This work was supported by the Canadian International Development Agency's Southeast Asia Program.

5. REFERENCES

Badawi, W., Walsh, T., and Jhamtani, H., eds 1998. *Forest and land fires in Indonesia: Impacts, factors and evaluation.* Jakarta, Indonesia: State Ministry for Environment, Republic of Indonesia. 185 p.

Englefield, P., Lee, B. S., and Suddaby, R. 2000. *Spatial Fire Management System*. *ESRI User Conference Proceedings* Redlands, California: Environmental Systems Research Institute.

Harger, J. R. E. 1995. *ENSO variations and drought occurrence in Indonesia and the Philippines*. Atmospheric Environment. 29(16):1943-1955.

Ikegami, M., Okada, K., Zaizen, Y., Makino, Y., Jensen, J. B., Gras, J. L., and Harjanto, H. 2001. *Very high weight rations of S/K in individual haze particles over Kalimantan during the 1997 Indonesian forest fires.* Atmospheric Environment. 35:4237-4243.

Jun-Ichi, H., and Sribimawati, T. 1998. *Catalogue and sample plotting of daily rainfall data for 1961-90 at 157 stations in Indonesia.* Yamanaka, M. D., Editor. Climatology of Indonesian Maritime Continent. 90 p.

Khandekar, M. L., Murty, T. S., Scott D., and Baird, W. 2000. *The 1997 El Niño, Indonesian forest fires and the Malaysian smoke problem: a deadly combination of natural and man-made hazard*. Natural Hazards. 21:131-144.

Kita, K., Fujiwara, M., and Kawakami, S. 2000. *Total ozone increase associated with forest fires over the Indonesian region and its relation to the El Nino-Southern Oscillation*. Atmospheric Environment. 34(17):2681-2690.

Lawson, B.D. and Dalrymple, G.N. 1996. *Ground-truthing the Drought Code: field verification of overwinter recharge of forest floor moisture*. Can. For. Serv., Victoria, BC. FRDA Rep. 268. 21 p.

Lawson, B.D., Frandsen, W.H., Hawkes, B.C., and Dalrymple, G.N. 1997. *Probability of sustained smoldering ignition for some boreal forest duff types*. Can. For. Serv., Edmonton, Alberta. For. Manage. Note 63. 11 p.

McAlpine, R.S. 1990. *Seasonal trends in the Drought Code component of the Canadian Forest Fire Weather Index System*. For. Can., Petawawa, Ont. Inf. Rep. PI-X-97. 36 p.

Siegert, F. and Hoffmann, A. A. 2000. *The 1998 forest fires in East Kalimantan (Indonesia): a quantitative evaluation using high resolution, multitemporal ERS-2 SAR images and NOAA-AVHRR hotspot data.* Remote Sensing of Environment. 72(1):64-77.

Turner, J.A. 1972. *The Drought Code component of the Canadian Forest Fire Behavior System*. Can. For. Serv., Ottawa, Ont. Publ. 1316. 14 p.

Van Wagner, C.E. 1987. *Development and structure of the Canadian Forest Fire Weather Index System*. Can. For. Serv., Ottawa, Ont. For. Tech. Rep. 35. 37 p.